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Assessing Hydrologic Impacts of Future Land Cover Change Scenarios in the San Pedro River (U.S./Mexico)

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Background

Long-term land-use and land cover change and their associated impacts pose critical challenges to sustaining vital hydrological ecosystem services for future generations. Scenario analysis is an important tool to help understand and predict potential impacts caused by decisions regarding conservation and development. In this study, a methodology was developed to characterize the hydrologic impacts of future urban growth through time. This project 1) describes a methodology for adapting the Integrated Climate and Land-Use Scenarios (ICLUS, Bierwagen et al., 2010; EPA, 2009; EPA, 2010) data for use in the Automated Geospatial Watershed Assessment Tool (AGWA; Miller et al. 2007) as an approach to evaluate basin-wide impacts of development on water-quantity and -quality, 2) presents initial results from the application of the methodology to evaluate water scenario analyses related to baseline condition and forecasted changes, and 3) discusses implications of the analysis for the San Pedro River, an arid international watershed on the U.S./Mexico border, (Figure 1).

Methodology

The methodology developed in this project to ascertain local vulnerabilities and cumulative impacts associated with basin-wide development is a multi-step process. First, the project/watershed extent must be defined to ensure that data are obtained for the entire study area. Land cover data must then be converted to a format compatible with AGWA in a manner that is consistent with existing land cover in the study area. Next, soils and precipitation data for the study area must be located and extracted. Finally, AGWA is used to parameterize and run the Soil and Water Assessment Tool (SWAT; Neitsch et al. 2002; Srinivisan and Arnold 1994) for the baseline condition and future land cover/use scenarios, (Figure 2). Future land cover/use scenarios are represented by ICLUS housing density maps generated in decadal intervals from 2010 to 2100, reclassified to National Land Cover Database 2006 land cover classes for use in AGWA to parameterize the SWAT model.

Study Location & Future U.S. Populations

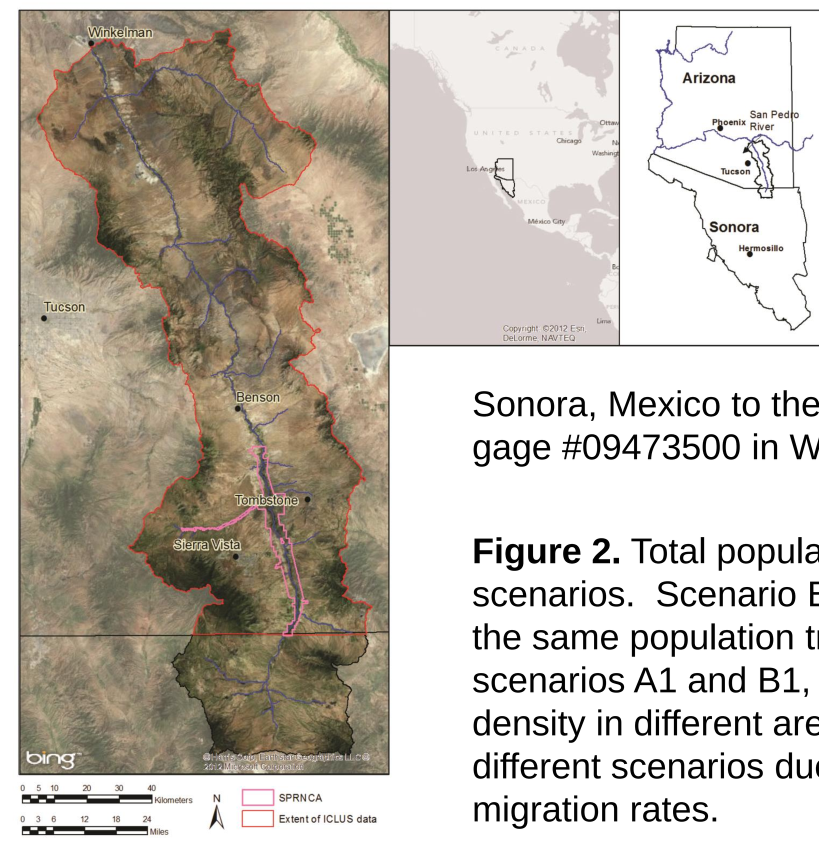
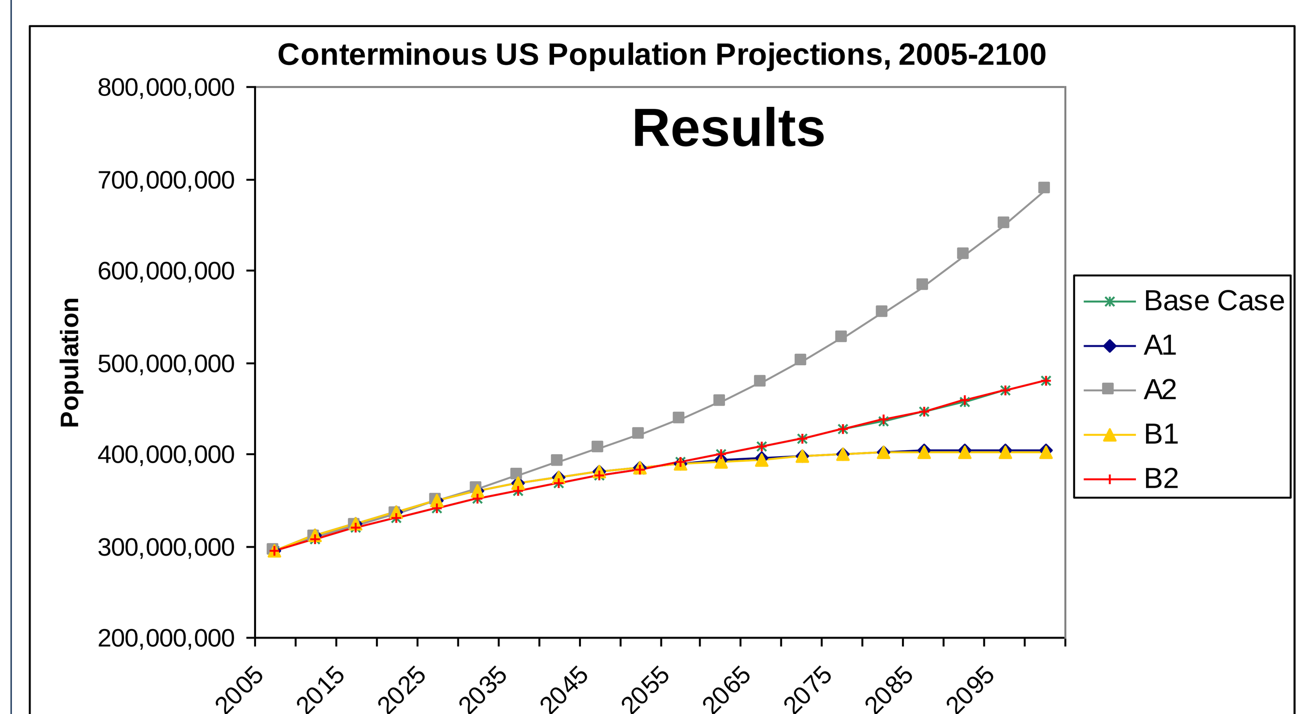


Figure 1. The study area contains the entire San Pedro Watershed (~11500 km²) from Sonora, Mexico to the historic USGS stream gage #09473500 in Winkelman, AZ.

Figure 2. Total population under five ICLUS scenarios. Scenario B2 and the base case have the same population trajectories, as do scenarios A1 and B1, however the housing density in different areas varies under the different scenarios due to different domestic migration rates.



Conclusions

The results emphasize the importance of including scrutiny of individual subwatersheds and the explicit areas that change in a basin-scale assessment as the impacts at the subwatershed scale and below can be much greater than at the basin scale (Figure 4). Because the San Pedro Watershed encompasses so much area, and a significant portion is undevelopable, the changes that are occurring in developable subwatersheds may need to be examined at a larger scale to determine if hydrologic impacts would be unacceptable that might otherwise be captured if the impacts were occurring basin-wide and triggering a larger, unacceptable impact at the watershed outlet. Thus any interests in cumulative effects should be addressed at the subwatershed versus basin scale for this western watershed or any others like it which are characterized by large tracts of land in the public domain which are undevelopable, and therefore not subject to direct urbanization impacts.

References

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Results

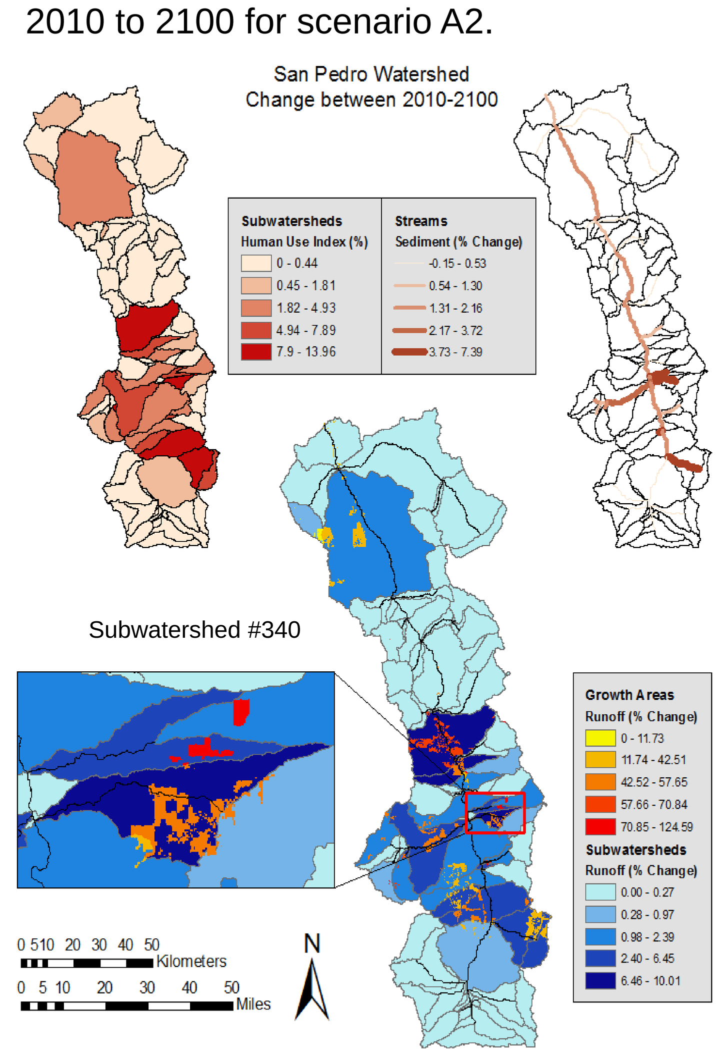
All scenarios resulted in an increase to the Human Use Index metric averaged over the entire watershed. Human Use Index (HUI, adapted from Ebert and Wade, 2004) is the percent area in use by humans. It includes NLCD land cover classes "Developed, Open Space"; "Developed, Low Intensity"; "Developed, Medium Intensity"; "Developed, High Intensity"; "Pasture/Hay"; and "Cultivated Crops". The ICLUS A2 scenario resulted in the largest increase of the HUI, 2.21% in year 2100 for the entire watershed (see Figure 3).

Similarly to the increases in HUI over the entire watershed, both simulated runoff and sediment yield increased at the watershed outlet over time for all scenarios; likewise, scenario A2 experienced the largest percent change in surface runoff and sediment yield, 1.04% and 1.19%, respectively (see Figures 5 – 7). Percent change was calculated using the following equation:

$$\frac{([decade_i] - [base_i])}{[base_i]} \times 100$$

where [$decade_i$] represents simulation results for a decade from 2020 through 2100 for a given scenario (i) and [$base_i$] represents the baseline 2010 decade for the same scenario.

Figure 3. Change in Human Use Index (HUI), sediment yield, and surface runoff (both average and explicit) in percent from 2010 to 2100 for scenario A2.



Explicit percent change, or change in the growth areas, is calculated by dividing the effective percent change, i.e. the average percent change over the entire subwatershed, by the ratio of changed land cover area to entire subwatershed area.

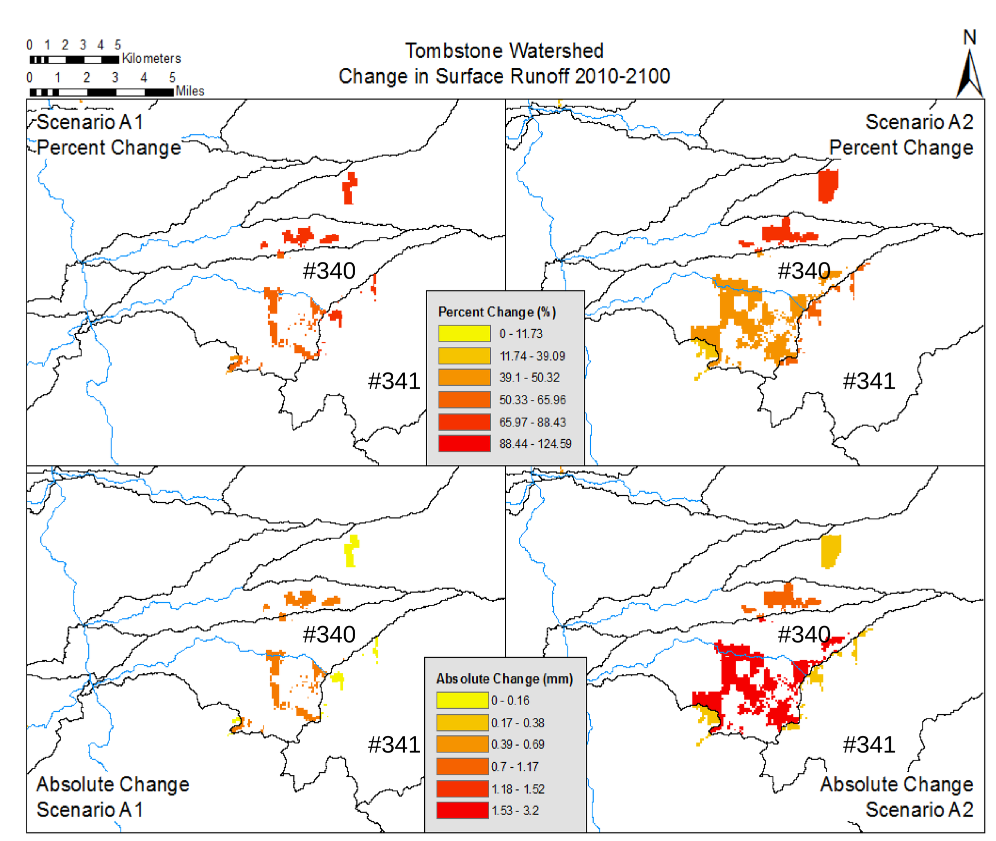
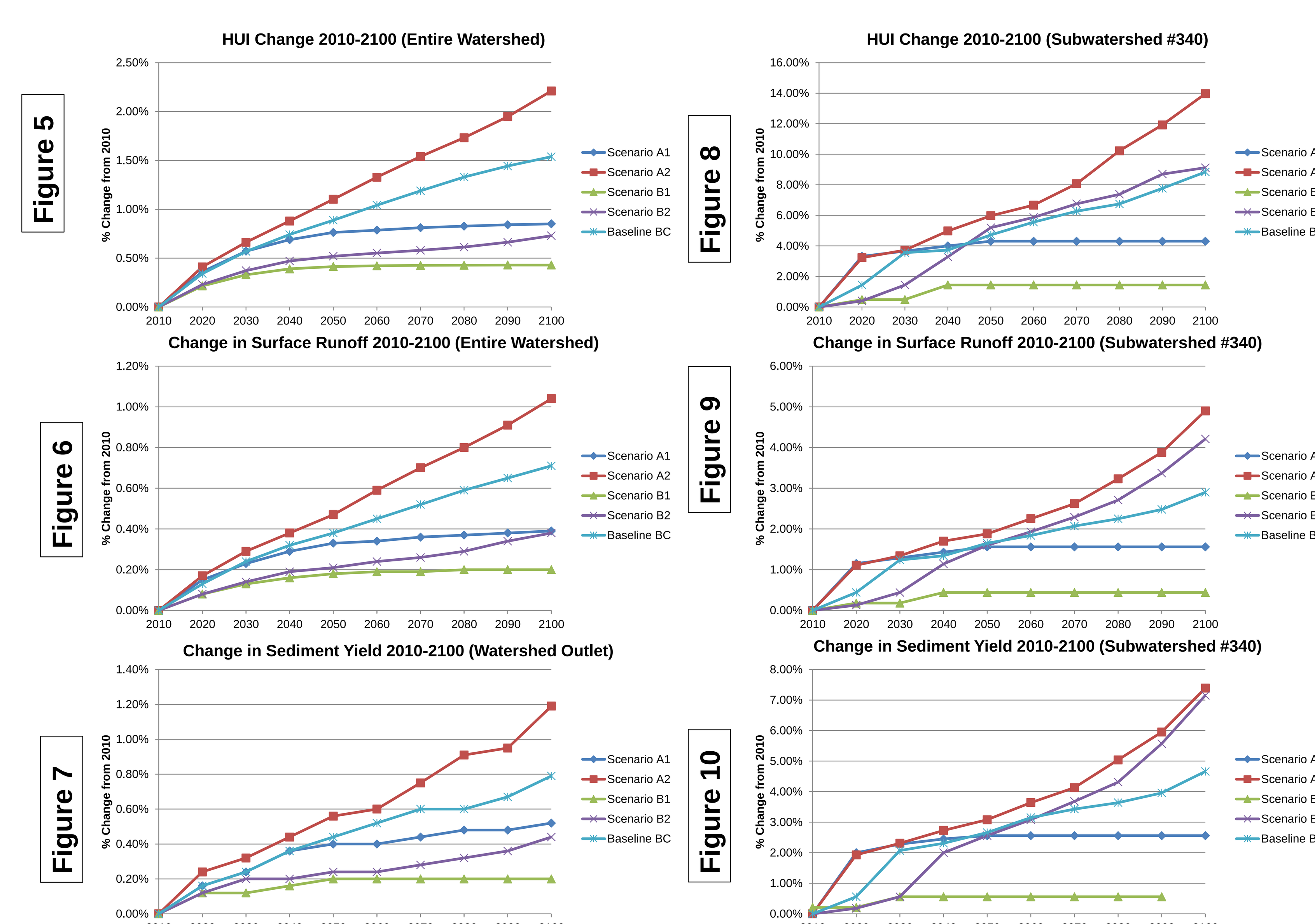


Figure 4. Subwatersheds #340 and #341 for scenarios A1 and A2 from 2010 to 2100 show how a larger absolute change in one scenario can undergo a smaller explicit percent change (average subwatershed percent change divided by the ratio of changed land cover area to entire subwatershed area). Explicit percent change emphasizes that local change may be much greater than average watershed or even average subwatershed percent change can describe.



Figures 5 through 10. Change in Human Use Index (HUI), sediment yield, and surface runoff for all scenarios and decades at the watershed outlet (left) and at the subwatershed with the highest change (right). The pattern is similar at the watershed outlet and the selected subwatershed, but the magnitude of change is greater at the subwatershed scale because at the subwatershed scale, local changes are not attenuated by large undevelopable areas.

scenario (i
2010 deca

EPA